INTRODUCING PRECISE LEVELLING FOR STABILITY RESEARCHES IN BUILDINGS SITUATED IN THE NEIGHBOURHOOD OF AREAS OF INTENSIVE BUILDING WORKS

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SUMMARY

Erecting new objects, modernizing the network of underground armature, changes in communication system are accompanied by ground works carried out at considerable depths. Such works often cause changes in traffic engineering, directing traffic to local routes, unprepared for it's reception. Such occurrences cause changes in the construction of existing buildings. In the work, a network of universal precise levelling will be presented, which aims to define if the visible changes in buildings construction have their reflection in the settlement of their foundation.

1. INTRODUCTION

Works aimed at defining the stability of various engineering objects is a geodesy main issue. The threat of their stability can result from many factors. To main factors lowering durability of a building which can occur before it is given to exploration belong: non-beneficial and insufficient recognition of geological and hydrological conditions of the subsoil, faults in building and assembly, hidden faults in building materials. During exploitation, especially in the case of an object located in an urban area, wear of the construction due to exploitation, running building works connected with ground works, intensive traffic of vehicles of high tonnage and unpredictable ecological disasters occur. Apart from the above mentioned factors, also others can influence the durability of a building. (Bryś, Przywłocki, 1998), and each presented list can be incomplete.

Such an unbeneficial situation for the durability of the building has actually occurred in the region of Grunwaldzki Square in Wrocław, where most didactic and social buildings of the University of Environmental and Life Sciences are situated. The alterations to the communication system which are being carried out there, and most of all building works connected with the sufficient lowering of ground water level can have an important influence on the durability of construction of those buildings (Wolski, 2001). A net of precise levelling has been set for monitoring the cracking of walls of some buildings which has occurred and has it's origin in settlement of their foundations.

2. GENERAL CHARACTERISTIC OF RESEARCH NETWORK.

Measurements of precise levelling included not only buildings, where the signs of construction damage were visible (fig. 1) but also other objects of the University of Environmental and Life Sciences. The first ones were the Didactic Centre building, University Library, the Engineering of Shaping the Environment building, student houses Talisman and Labyrinth. The others were: The Main Building, building of Veterinary Medicine, building of Geodesy and student houses Centaur and Zodiac. The reasons for the damage are certainly complex and different for separate buildings. Numerous cracks in the walls of student house Labyrinth result mainly from its close situation directly on the bank of the Old Odra River and were noticed at the beginning of 1960s, but they intensified after the flood in 1997. Damage to the University Library was noticed at the turn of the century (first signals occurred in 1997). Therefore their source may be the difference in water level during the flood, and the fact that there is a layer of earthwork ground under the building foundation. (Krzyśków, Sowa, 2001; Rybak, 2002). The cracks in the walls of part of the Student House Talisman, occurred because of moving heavy circular traffic from the modernized part of Grunwaldzki Square into Grunwaldzka Street which was unprepared for receiving such traffic where the road surface was very damaged anyway. A crack in the construction of the building of Engineering of Shaping the Environment (fig. 1) probably resulted from excavating a trench for a new building of the Didactic centre. The reason for the cracks in the Centre are not yet known, but their occurrence can be connected with the building of two new, huge service objects "Grunwaldzka Gallery" and "Grunwaldzki Center", where the depth of trenches was about 5-7 meters, which was connected with sufficient lowering of ground water.

110 stabilized controlled bench –marks (fig. 2) and 23 national bench-marks which create the reference network were included into measurements. Totally 246 levelling sections which included from 1 do 8 stations were measured (fig. 3).

The measurements were taken within student practice of the 3rd year on geodesy engineering in July and August 2006. The heads of the practice dr. eng. Janusz Kuchmister, dr. eng. Kazimierz Ćmielewski and the manager of the practice dr. eng. Krzysztof Mąkolski were supervising the works. The first control measurement is scheduled for June – July 2007.

Four checked Ni 007 levelling and 4 sets of invar measuring rods were used for measurements. As there was no possibility of comparison of such and amount of rods, the ones in our possession were compared to new invar measurement rods, not used in terrain measurements, which have a comparison certificate. In the result of this action, 8 rods with similar division characteristics were selected and paired into 4 pairs.

To equalize the levelling network an average error of a singular station has been defined, $m_0 = \pm 0{,}20$ mm. In result of the equalization we have received average errors of measured bench marks within limits for defining the height of controlled bench marks which is in limits proposed for those sorts of objects (Wolski, 2001).

Fig. 1. Cracking of a wall: Engineers of Shaping an Environment building.

Fig. 2. Controlled bench mark on the Didactic Centre building.

Fig. 3. Sketch of a control-measurement network.

3. EVALUATION OF STABILITY OF REFERENCE BENCH MARKS

The research into stability of tie bench markers can be done by various methods, including:

- a way of controlling differences of excedance for bench markers pairs according to Hermanowski (Lazzarini et. al. 1977),
- a way using the method of resistant estimation described in works (Kamiński, Wiśniewski, 1998; Osada, 2002),carried out by "Niwelacja" program (Osada 2000), introduced among others in the work of Muszyński et al., 2005,
- Method using a global test for cohesion of a network of two monitoring cycles (Pelzer, 1971; Niemeier, 1980).

For verification of stability of points by all three above mentioned methods it is important to posses direct, terrain, results of measurement of height differences, and the final result is achieved only after the second measurement.

For earlier, initial analyses of usefulness of measured bench markers of national levelling and tying it to described levelling network, we have carried out analyses of the stability of bench marks, based on historical materials:

1. Catalogue Höhenfeftpunkte in Breslau, elaborated on the base of measurements from 1924-1931, called measurement cycle A.
2. catalogue of levelling points of Wroclaw city, elaborated on the base of measurements from 1967 - 1978, called measurement cycle B.
3. catalogue of levelling points of Wroclaw city, elaborated on the base of measurements from 1998 (currently valid), called measurement cycle C.

Because the above mentioned catalogues include only equalized heights for the choice of stable points in particular periods of time, ordinates of bench markers were inserted using SNET program (Kontny, 1993), matching catalogue data with results of initial measurement which were carried out in 2006. The choice of bench markers was made using the iterative method, assuming the average matching error below 2 mm as criteria of stability. In result of the carried out analyzes, it was concluded that from the first measuring cycle (measuring cycle A) four bench markers: W-1471, W-1470, W-284, W-469. From the next measuring cycle B - two additional bench markers: W-2217, AM-7528, and from measuring cycle C - additionally seven further bench marks: W-1464, W-1465, W-1208, W-49, W-112, W-1459 and W-1270 (fig. 3). Such a big choice of stable bench marks, defined for the measured network, allows us to assume that the current range of the network is appropriate.

4. DEFINING BUILDING SETTLEMENT OF THE DIDACTIC CENTRE

The Didactic Centre building was given to exploitation in October 2005 and already in October 2006 the first cracks were noticed in the building's walls. That was the reason for performing a control measurement of the building in reference to the first measurement of the research network .Because of the representative form of the object's elevation only four control bench markers were stabilized on the object. Up to the present year totally three control measurements were performed (15th October 2006, 15 March 2007 and 15th April 2007). The sketch of the measurement network, which constitutes a fragment of the whole control -measurement network is presented in fig. 4. Control measurements are performed with DNA03 coded levelling of the highest precision from Leica Company. The measurements were connected to the closest, currently stable reference bench marks W-384, W-1469. Values of vertical shifts and errors of those shifts for bench marks situated on the building in the Didactic Centre were presented in table 1. Shifts in the time frame are presented in fig. 5.

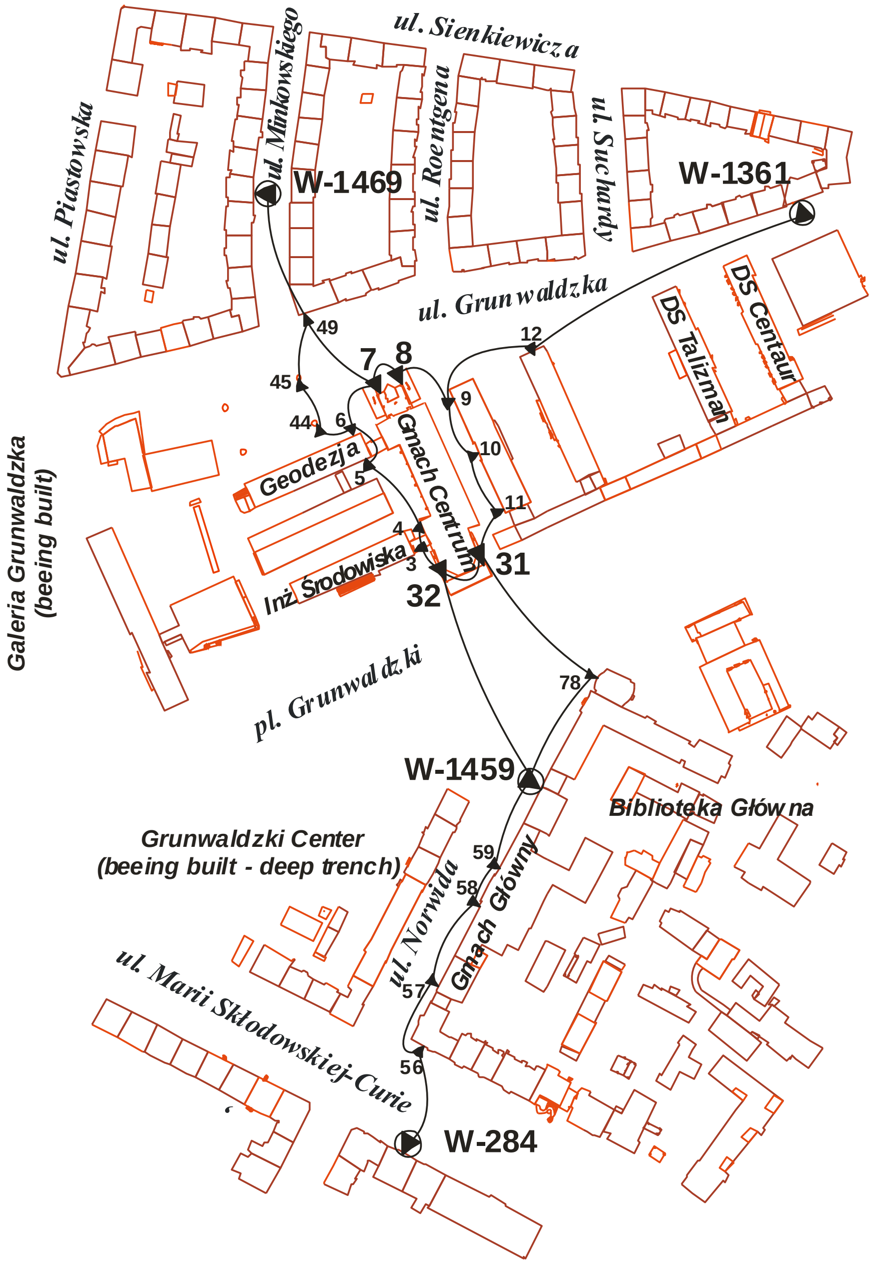

Fig. 4. A network measurement sketch of the Didactic Centre.

Table 1. Vertical shifts of bench marks situated on the Didactic Centre.

Measurement Data	Bench Mark 7		Bench Mark 8		Bench Mark 31		Bench Mark 32	
	Δp [mm]	$m_{\Delta h}$ [mm]	Δp [mm]	$m_{\Delta h}$ [mm]	Δp [mm]	$m_{\Delta h}$ [mm]	Δp [mm]	$M_{\Delta h}$ [mm]
15.10.2006	-0,81	±0,35	-1,06	±0,34	-1,44	±0,41	-1,10	±0,37
15.03.2007	-0,59	±0,28	-0,74	±0,31	-2,08	±0,33	-1,13	±0,33
15.04.2007	-0,40	±0,35	-0,79	±0,36	-1,57	±0,37	-0,83	±0,35

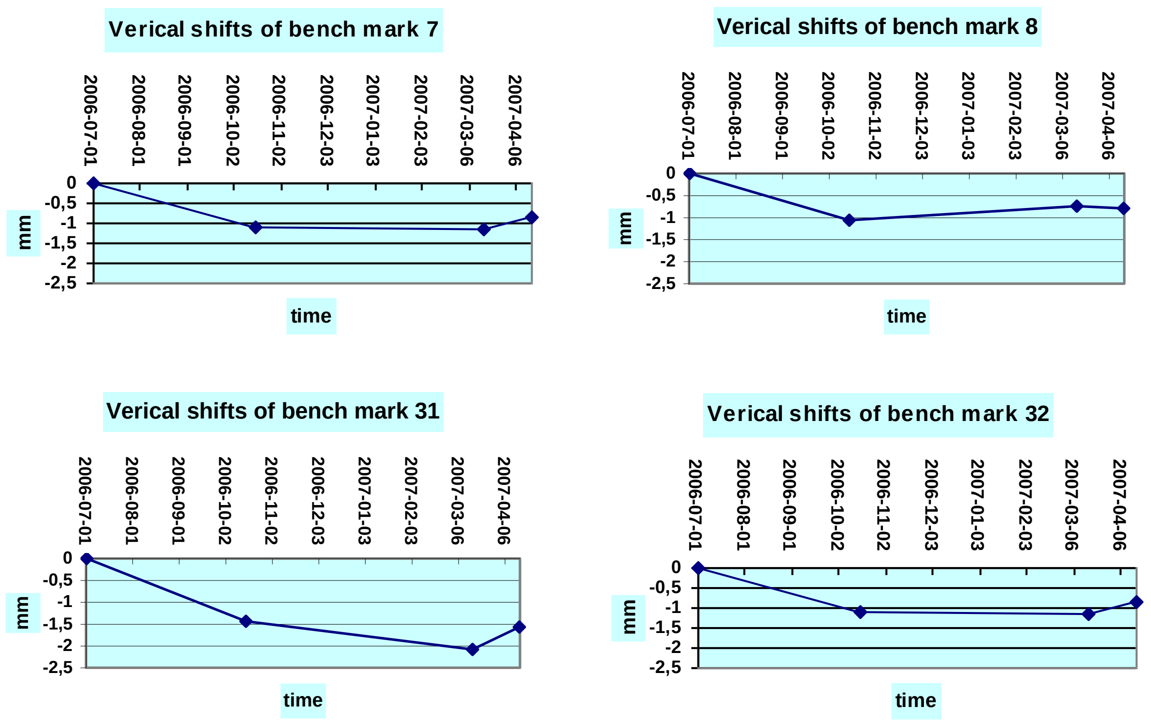

Fig. 5. Vertical shifts of bench marks situated on the Didactic Centre building.

Defined vertical shifts have a settlement character and their values although not huge are, in most cases, important taking into consideration the criteria of precision of their definition. A question arises in such a situation whether those small settlements could cause wall cracking of the Didactic Centre. A partial answer to that question can be given by performing analytic - graphic analyses of settlement interpretation (Czaja, 1983; Wolski, 2001). The Didactic Centre building was built on a concrete block that is why it is important if the size and location of defined vertical shifts of measured bench marks does not disturb the rigidity of mass of the object. The results of the performed calculation of rigidity parameters of the building are presented in table 2.

Table 2. Geometrical elements of analyses of analytic - graphic analyses of settlement interpretation of the Didactic Center building.

Measurement data	**15.10. 2006**	**15.03. 2007**	**15.04. 2007**
Gradient along axis X [mm/m]	**0,004**	**0,009**	**0,006**
Gradient along axis Y [mm/m]	**0,015**	**0,032**	**0,029**
Maximal gradient mm/m]	**0,015**	**0,033**	**0,030**
Azimuth of maximal gradient [g]	**123,43**	**126,77**	**123,32**
Vertical shift of the middle of the object [mm]	**-0,011**	**-0,011**	**-0,009**
Approximation error [mm] - m_a	**±0,40**	**±0,23**	**±0,01**
Average value of bench markers height errors [mm]- $m_{\Delta śr}$	**±0,37**	**±0,31**	**±0,36**
Criteria of definition of "rigid mass" $m_a \leq 2m_{\Delta śr}$	**competed**	**competed**	**competed**

To summarize the results presented in table 2 it is concluded that although the defined bench markers settlement are important from a geodesy point of view, their location does not cause variation of mass of the Didactic Center's rigidity. However to define the reasons for wall cracking it is proposed to perform stabilization and measurement of 44-6 new controlled bench marks located on carrying pillars of the object construction.

SUMMARY

The received results of measurements of vertical shifts of the building of the Didactic Centre confirmed the validity of the decision to carry out the researches on settlement of most buildings of the University of Environmental and Life Sciences. They have also shown the necessity for stabilization of a higher number of control points (Wolski, 2001) for achieving wider information about the character of object deformation in the way it was carried out for other objects (fig. 3).

Introducing precise code levelling DNA 03 to control measurements improved organization of measurement and calculating works in a significant way and also contributed to improvement of achieved results.

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